Research Article

Relationship between electrical conductivity and colostrum quality in farm level

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ABSTRACT

Good quality colostrum intake is essential component in calf health programs. There are different methods to determine the quality of colostrum. The aim of the present study is to investigate the relationship between Immunoglobulin G (IgG), which is used to determine colostrum quality, and electrical conductivity in farm level. Two groups were performed according to results of IgG analyses. Samples which had <50 mg/mL IgG concentration were assigned into group 1 (G1, n=27) and accepted as insufficient quality colostrum. Samples that had >50 mg/mL IgG concentration were accepted as good quality colostrum and assigned into group 2 (G2, n=68). IgG concentrations were measured by ELISA, then the electrical resistance (ER) and conductivity (EC) measured by Draminski Mastitis Detector (MDQ4, MDQ). MDQ and ER results were statistically higher in G2, and EC results were statistically higher in G1, but difference was not statistically significant (P>0.05) in G1, there was moderate positive correlation between IgG and ER, EC and MDQ (P<0.01). Presented study revealed strong correlation between EC and IgG concentration in low-quality colostrum. There are lots of variables that effect conductivity and resistance of colostrum, so to eliminate uncertainties of use of MDQ further research must be done. Moreover, MDQ readings show considerable potential for being useful tools in colostrum management systems to improve calf health in dairy farms.

Keywords: Colostrum, dairy cow, electrical conductivity, electrical resistance, IgG

INTRODUCTION

During the last weeks of pregnancy and first days of post-partum period colostrum is the first secretion of mammary gland that is composed of different components including immunoglobulins (Baumrucker et al., 2022; Buczinski and Vandeweerd, 2016). Cows have an epitheliochorial placenta (Kara and Ceylan, 2021; Turini et al., 2020). Due to this placenta type, calves are born hypogammaglobulinemic (Kara and Ceylan, 2021). In bovine species, because of being born aggloblunemic, colostrum is crucial and critical. Though white blood cells and cytokines are important for calf immunity, IgG has critical role (Stelwagen et al., 2009). Sufficient and punctual supply of colostrum is vital for newborn calves (Immer et al., 2022). The transfer of immunoglobulins (Ig) from cow to fetus is prevented because placenta membranes have sparse permeability. Calves are born with low level of antibody on account of Ig cannot pass through placenta membranes (Ahmann et al., 2021). Intestinal permeability to IgG absorption rapidly decreases after birth (Hare et al., 2020) which makes delivering good quality colostrum as soon as possible after birth crucial. Therefore, good quality colostrum intake is essential component in calf health programs (Godden et al., 2019).

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Intestinal permeability to IgG absorption rapidly decreases after birth (Hare et al., 2020) which makes delivering good quality colostrum as soon as possible after birth crucial. Therefore, good quality colostrum intake is essential component in calf health programs (Godden et al., 2019). To prevent infectious diseases, getting colostrum right after birth with high immunoglobulin concentration is indispensable. If calves do not drink enough high-quality colostrum or quality of colostrum is not enough, failure of passive transfer (FPT) develops (Topal et al., 2018; Turini et al., 2020). So, to achieve good passive transfer, colostral IgG content is very important (Gelsinger et al., 2015).

Management of good colostrum leads to decrease in morbidity and mortality in the first days of life (Ahmann et al., 2021). Also, it effects further rearing, first calving age, further body weight and milk yield (Furman-Fratczak et al., 2011; Kessler et al., 2020). To complete successful passive transfer, colostrum should be given as soon as possible, in sufficient quantity and quality (Jaster, 2005). In cow colostrum, most important Igs are IgG, IgA and IgM. Main component of cattle colostrum is IgG which is up to 95% of total Ig concentration (Godden et al., 2008; Martin et al., 2021). The quality of colostrum could be measured by concentration of IgG (Crouch et al., 2000; Godden et al., 2019). Direct methods such as RID and ELISA represent gold standard for estimating the IgG concentration of colostrum (Ahmann et al., 2021). Generally, IgG concentration of colostrum is wanted to be higher than 50mg/mL (McGuirk and Collins, 2004). Calves need to receive 100-200 g IgG to have successful passive transfer immunity. Considering a newborn calf drink 3-4 liters colostrum withing first 6 hours to achieve success and based on these facts 50 g/L IgG concentration becomes arbitrary cut-point to define colostrum quality (Buczinski and Vandeweerd, 2016; McGuirk and Collins, 2004; Morrill et al., 2012). This threshold has been widely used to define the quality of colostrum by different researchers (Chigerwe and Hagey, 2014; Godden et al., 2019; Immer et al., 2022).

There are different methods to determine the quality of colostrum. Some methods measure Ig concentration which are accepted as direct methods. On the other hand there also indirect methods, whereas these methods give summary about the Ig concentration based on change in the physical and chemical properties of colostrum (Ahmann and et al., 2021). On farm level, measurement of colostrum quality should be easy to use, accurate and effective. Moreover, the costs should be kept minimal for feasible dairy cow industry (Bartens et al., 2016; Bielman et al., 2010). The aim of the present study is to investigate the relationship between IgG, which is used to determine colostrum quality, and electrical conductivity in farm level.

MATERIALS AND METHODS

Animals and sampling

The study was conducted in dairy farm of Holstein-Friesian breed. General condition and udder health of animals were evaluated by clinical examination. Udders of the cows were examined visually and by palpation for general mastitis changes (redness, pain, swelling, heat). Cows who had general signs of diseases (fever, loss of appetite, weight loss, lethargy) were not included in the study. The material of the study consisted of colostrum of 96 Holstein-Friesian cattle.

Groups

Two groups were performed according to results of IgG analyses. Samples which had <50 mg/mL IgG concentration were assigned into group 1 (n=27) and accepted as insufficient quality colostrum. Samples that had >50 mg/mL IgG concentration were accepted as good quality colostrum and assigned into group 2 (n=68).

Samples

Colostrum was taken from the cows by using single milking machines within the first hour after birth. All colostrum samples were labeled and stored in freezers at -20ºC until analyses were done.

Laboratory analysis

IgG analyzes and electrical conductivity of samples were performed at same day. All frozen samples were thawed at room temperature and IgG concentrations were measured by ELISA kits (Biox, Belgium) then the electrical resistance was measured 4 times repeatedly using the Draminski mastitis detector (MD4Q-4896, Olsztyn, Poland). The MD4Q measures electrical resistance in the range of 10-1000 Ω. The electrical resistance (ER) value measured by MDQ was converted into electrical conductivity (EC) as stated before (Khatun et al., 2019).

ER (Ω) = unit read in MDQ / 1.944

EC (1000 mS) = EC (1 S) = 1 reciprocal ohm (1/Ω)

Statistical analyses

Statistical analyses were performed using IBM SPSS Statistics software Version 23.0 and MedCalc 16 statistical software. Before performing the statistical analysis, data were examined for parametric test assumptions. Descriptive statistics for each variable were calculated and presented as "Mean ± Standard Error of Mean (SEM)". To test the differences in IgG, ER, EC and MDQ parameters between groups (Low-High IgG), student t test was used. Pearson correlation coefficient was performed to assess the correlation between IgG, ER, EC and MDQ. In addition, Pearson correlation coefficient was used to evaluate the correlation between IgG, ER, EC and MDQ for each group (low IgG and high IgG) separately. A receiver operating characteristics (ROC) analysis was performed to calculate the electrical conductivity diagnostic test characteristics (sensitivity, specificity, positive likelihood ratio and negative likelihood ratio) for evaluating low-high IgG. Areas under the ROC curves (AUC) were assessed to determine the discrimination ability of the IgG level. The statistical significance level was set at P<0.05.

RESULTS

Immunoglobulin G levels were statistically higher in group 2 (G2) than group 1 (G1) and difference was statistically significant (P<0.001). MDQ and ER results were statistically higher in G2, and EC results were higher in G1, but difference was not statistically significant (P>0.05). Results of IgG, MDQ, ER and EC are presented in Table 1.

Table 1. Results of IgG, ER, EC and MDQ analyses

Parameters	Groups (Mean ± SEM)		P value
	G1 (n=27)	G2 (n=68)	
IgG (mg/mL)	28.97±2.60	109.70±5.67	<0.001
ER (ohm)	299.21±9.44	313.17±6.29	0.234
EC (S)	3.43±0.11	3.28±0.06	0.233
MDQ (Units)	581.67±18.35	608.80±12.23	0.234

IgG: Immunoglobulin G; ER: Electrical Resistance; EC: Electrical Conductivity; MDQ: Results of Draminski MD4Q

In G1, G2 and without groups, high positive correlation between ER, EC and MDQ were found (P<0.001). In addition, in G1, there was moderate positive correlation between IgG and ER, EC and MDQ (P<0.01). The cross correlations of IgG, ER, EC, and MDQ results within groups and without grouping are shown in Table 2, 3 and 4.

Table 2. Correlations between IgG, ER, EC and MDQ without groups (n=95)

Parameters	IgG	ER	EC	MDQ
IgG	1	0.180	-0.186	0.180
ER		1	-0.981***	0.994***
EC			1	-0.981***
MDQ				1

***Correlation is significant at the 0.001 level (2-tailed). IgG: Immunoglobulin G; ER: Electrical Resistance; EC: Electrical Conductivity; MDQ: Results of Draminski MD4Q

Table 3. Correlations of IgG, ER, EC and MDQ in G1 (n=27)

Parameters	IgG	ER	EC	MDQ
IgG	1	-0.514**	0.500**	-0.514**
ER		1	-0.982***	0.995***
EC			1	-0.982***
MDQ				1

: Correlation is significant at the 0.01 level (2-tailed). *: Correlation is significant at the 0.001 level (2-tailed). IgG: Immunoglobulin G; ER: Electrical Resistance; EC: Electrical Conductivity; MDQ: Results of Draminski MD4Q

Table 4. Correlations of IgG ER EC and MDQ in G2 (n=68)

Parameters	IgG	ER	EC	MDQ
IgG	1	0.208	-0.223	0.208
ER		1	-0.981***	0.992***
EC			1	-0.981***
MDQ				1

***: Correlation is significant at the 0.001 level (2-tailed). IgG: Immunoglobulin G; ER: Electrical Resistance; EC: Electrical Conductivity; MDQ: Results of Draminski MD4Q

Three different ROC analysis were performed to determine thresholds for ER, EC and MDQ values to predict IgG values. The results of ROC curves analysis are presented in Table 5.

The ROC curves for thresholds between ER, EC, MDQ and IgG were shown in Figure 1.

Table 5. ROC curve analysis for cut-off and threshold values

Variables	Threshold	Se	%95 Cl for Se	Sp	%95 Cl for Sp	AUC	+ LR	- LR	p
ER	> 253.34	92.75	83.9- 97.6	25.93	11.2-46.3	0.574	1.25	0.28	0.242
EC	≤ 3.89	92.75	83.9-97.6	25.93	11.2-46.3	0.574	1.25	0.28	0.264
MDQ	> 492.5	92.75	83.9-97.6	25.93	11.2-46.3	0.574	1.25	0.28	0.424

IgG: Immunoglobulin G; ER: Electrical Resistance; EC: Electrical Conductivity; MDQ: Results of Draminski MD4Q

DISCUSSION

The objective of the presented study was the evaluation of electrical conductivity and resistance compared with ELISA assessment of IgG concentrations in frozen thawed colostrum. The hypothesis of the study assumed that there was a connection between amount of IgG which is determines the quality of bovine colostrum and electrical conductivity. The present study show that electrical conductivity and resistance might be useful indicators for determination of colostrum quality. The difference of IgG results between groups were statistically significant. The difference in IgG concentrations may have been due to calving season, nutrition, environment, parity, and timing of colostrum collection (Conneely et al., 2013; Gulliksen et al., 2008; Moore et al., 2005). Samples were collected in random order and sampling took place during whole year, so IgG concentrations may be affected from both season and nutrition. In this manner, composition of the herd could not be represented by the samples. All colostrum samples were analyzed frozen and thawed. Though one freeze thaw cycle had little or no effect on some farm-level devices such as hydrometer and refractometer (Morrill et al., 2015), so it can be concluded that results and correlations of the study were not affected by freeze thaw cycles.

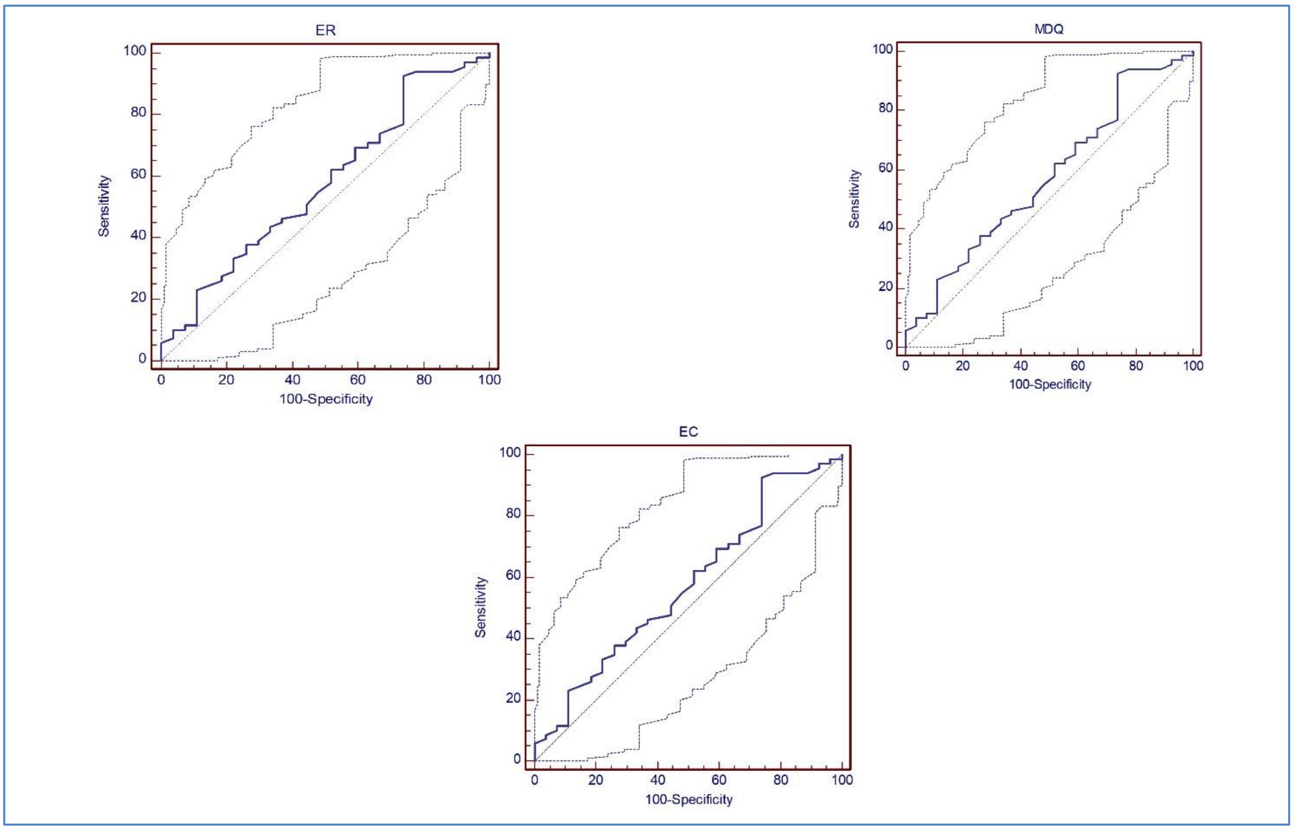

Figure 1. ROC curve graphs of ER, MDQ and EC. ER: Electrical Resistance; EC: Electrical Conductivity; MDQ: Results of Draminski MD4Q

Readings of MDQ between groups were not statistically significant. Since ER and EC are conversions of MDQ, difference of ER and EC between groups were not statistically significant as well. Average readings of MDQ for G1 and G2 were 581.67±18.35 and 608.80±12.23 respectively. Galfi et al. (2015) reported that at peak lactation (days 0-50), MDQ readings were between 260 and 700 (403±80.14). Our results were within their range but, higher than their average. MDQ readings are based on electrical conductivity. It was reported that healthy cow's milk conductivity is from 4.0 to 5.5 mS at 20ºC (Walstra, 1999). In addition, Kozheshkurt et al. (2021) indicated that electrical conductivity of whole colostrum was measured within the range of 0.37 and 0.43 S at 18±1ºC. Our results are not consistent with the previous studies. It was thought that there might be few reasons that conductivity of colostrum in both groups were lower than aforementioned studies. It is known that electrical conductivity is affected by temperature (Kozheshkurt et al., 2021). In the presented study, frozen colostrum samples were thawed at room temperature. Since average freezing point of cow milk is reported as -0.5ºC (Fox et al., 1998; Kuczaj et al., 2001; Navratilova et al., 2006), it shouldn't be assumed that after thawing process, temperature of samples was at room temperature. However, in the presented study temperature of samples were not analyzed, so it is not possible to determine exactly the effect of colostrum temperature on electrical conductivity. This is the most likely reason of the inconsistency with the reported studies and our results. Moreover, since electrical resistance is measured by formula from conductivity, it would be logically to expect similar results for ER.

Results of the study suggest that there is no relationship between EC, ER and IgG content of colostrum, but in low quality colostrum there were significant correlations between ER and IgG content. There were strong correlations between MDQ, ER and EC within groups and within all samples. Reason for those correlations was ER and EC are calculated from MDQ readings. There was not statistically significant correlation between IgG and EC in all samples, but correlation between IgG and electrical resistance was found in group 1. Also, EC levels were found higher and ER levels were lower in G1 than G2. Reason of that difference might be because of IgG and protein levels of groups. Colostrum has elevated level of immunoglobulins (Smolenski et al., 2007) and total protein of colostrum is made up almost 80% by immunoglobulins (McGrath et al., 2016). It is reported that protein level of colostrum effects electrical conductivity. Removal of protein fractions from colostrum resulted in significant increase in electrical conductivity (Kozheshkurt et al., 2021).

Electrical resistance and conductivity are simple measurements of milk and widely used in detection of subclinical mastitis in dairy cows as marker (Fernando et al., 1982; Galfi et al., 2015; Norberg et al., 2004) and has not been evaluated in determination of colostrum quality. ER and EC could be indicators of low-quality colostrum in farm level. However, present study showed that ER, EC and MDQ had high Se (92.75) but low Sp (25.93) for IgG content of colostrum.

CONCLUSION

In conclusion, Draminski Mastitis Detector tool have high sensitivity, but low specificity compared to one of the gold standard ELISA lab tests. However, present study revealed strong correlation between EC and IgG concentration in low-quality colostrum. There are lots of variables that effect conductivity and resistance of colostrum, so to eliminate uncertainties of use of MDQ further research must be done. Moreover, MDQ readings show considerable potential for being useful tools in colostrum management systems to improve calf health in dairy farms.

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Conflict of interest: The authors declared that there is no conflict of interest.

Ethical statement: This study was approved by the Kırıkkale University Animal Experiments Local Ethics Committee (Approval no: 14.09.2022-E.117740).

REFERENCES

Ahmann, J., Steinhoff-Wagner, J., & Büscher, W. (2021). Determining immunoglobulin content of bovine colostrum and factors affecting the outcome: A review. *Animals*, *11*(12), 3587. https://doi.org/10.3390/ani11123587

Bartens, M., Drillich, M., Rychli, K., Iwersen, M., Arnholdt, T., Meyer, L., & Klein-Jöbstl, D. (2016). Assessment of different methods to estimate bovine colostrum quality on farm. *New Zealand Veterinary Journal*, *64*(5), 263-267. https://doi.org/10.1080/00480169.2016.1184109

Baumrucker, C.R., Macrina, A.L., & Bruckmaier, R.M. (2022). Colostrogenesis: Role and Mechanism of the Bovine Fc Receptor of the Neonate (FcRn). *Journal of Mammary Gland Biology and Neoplasia*, *26*, 419-453. https://doi.org/10.1007/s10911-021-09506-2

Bielmann, V., Gillan, J., Perkins, N., Skidmore, A., Godden, S., & Leslie, K. (2010). An evaluation of Brix refractometry instruments for measurement of colostrum quality in dairy cattle. *Journal of Dairy Science*, *93*(8), 3713-3721. https://doi.org/10.3168/jds.2009-2943

Buczinski, S., & Vandeweerd, J. (2016). Diagnostic accuracy of refractometry for assessing bovine colostrum quality: A systematic review and meta-analysis. *Journal of Dairy Science*, *99*(9), 7381-7394. https://doi.org/10.3168/jds.2016-10955

Chigerwe, M., & Hagey, J.V. (2014). Refractometer assessment of colostral and serum IgG and milk total solids concentrations in dairy cattle. *BMC Veterinary Research*, *10*(1), 1-6. https://doi.org/10.1186/s12917-014-0178-7

Conneely, M., Berry, D., Sayers, R., Murphy, J., Lorenz, I., Doherty, M., & Kennedy, E. (2013). Factors associated with the concentration of immunoglobulin G in the colostrum of dairy cows. *Animal*, *7*(11), 1824-1832. https://doi.org/10.1017/S1751731113001444

Crouch, C., Oliver, S., Hearle, D., Buckley, A., Chapman, A., & Francis, M. (2000). Lactogenic immunity following vaccination of cattle with bovine coronavirus. *Vaccine*, *19*(2-3), 189-196. https://doi.org/10.1016/S0264-410X(00)00177-8

Fernando, R., Rindsig, R., & Spahr, S. (1982). Electrical conductivity of milk for detection of mastitis. *Journal of Dairy Science*, *65*(4), 659-664. https://doi.org/10.3168/jds.S0022-0302(82)82245-5

Fox, P.F., McSweeney, P.L., & Paul, L. (1998). Physical properties of milk. **In,** Dairy chemistry and biochemistry. 2nd ed., 321-343.

Furman-Fratczak, K., Rzasa, A., & Stefaniak, T. (2011). The influence of colostral immunoglobulin concentration in heifer calves' serum on their health and growth. *Journal of Dairy Science*, *94*(11), 5536-5543. https://doi.org/10.3168/jds.2010-3253

Galfi, A., Radinović, M., Milanov, D., Boboš, S., Pajić, M., Savić, S., & Davidov, I. (2015). Electrical conductivity of milk and bacteriological findings in cows with subclinical mastitis. *Biotechnology in Animal Husbandry*, *31*(4), 533-541. https://doi.org/10.2298/BAH1504533G

Gelsinger, S., Jones, C., & Heinrichs, A. (2015). Effect of colostrum heat treatment and bacterial population on immunoglobulin G absorption and health of neonatal calves. *Journal of Dairy Science*, *98*(7), 4640-4645. https://doi.org/10.3168/jds.2014-8790

Godden, S.M., Lombard, J.E., & Woolums, A.R. (2019). Colostrum management for dairy calves. *Veterinary Clinics: Food Animal Practice*, *35*(3), 535-556. https://doi.org/10.1016/j.cvfa.2019.07.005

Gulliksen, S., Lie, K., Sølverød, L., & Østerås, O. (2008). Risk factors associated with colostrum quality in Norwegian dairy cows. *Journal of Dairy Science*, *91*(2), 704-712. https://doi.org/10.3168/jds.2007-0450

Hare, K.S., Pletts, S., Pyo, J., Haines, D., Guan, L.L., & Steele, M. (2020). Feeding colostrum or a 1:1 colostrum:whole milk mixture for 3 days after birth increases serum immunoglobulin G and apparent immunoglobulin G persistency in Holstein bulls. *Journal of Dairy Science*, *103*(12), 11833-11843. https://doi.org/10.3168/jds.2020-18558

Immler, M., Büttner, K., Gartner, T., Wehrend, A., & Donat, K. (2022). Maternal impact on serum immunoglobulin and total protein concentration in dairy calves. *Animals*, *12*(6), 755. https://doi.org/10.3390/ani12060755

Jaster, E. (2005). Evaluation of quality, quantity, and timing of colostrum feeding on immunoglobulin G1 absorption in Jersey calves. *Journal of Dairy Science*, *88*(1), 296-302. https://doi.org/10.3168/jds.S0022-0302(05)72687-4

Kara, E., & Ceylan, E. (2021). Failure of passive transfer in neonatal calves in dairy farms in Ankara region. *Turkish Journal of Veterinary & Animal Sciences*, *45*(3), 556-565. https://doi.org/10.3906/vet-2011-26

Kessler, E.C., Bruckmaier, R.M., & Gross, J.J. (2020). Colostrum composition and immunoglobulin G content in dairy and dual-purpose cattle breeds. *Journal of Animal Science*, *98*(8), 5542-5549. https://doi.org/10.1093/jas/skaa237

Khatun, M., Bruckmaier, R., Thomson, P., House, J., & García, S. (2019). Suitability of somatic cell count, electrical conductivity, and lactate dehydrogenase activity in foremilk before versus after alveolar milk ejection for mastitis detection. *Journal of Dairy Science*, *102*(10), 9200-9212. https://doi.org/10.3168/jds.2018-15752

Kozheshkurt, V., Ivanov, I., Antonenko, Y., Katrich, V., Bozhkov, A., Gromovoy, T. (2021). Devising an express method for estimating the quality of colostrum and its components based on electrical conductivity. *Eastern-European Journal of Enterprise Technologies*, *1*(11), 109. https://doi.org/10.15587/1729-4061.2021.225007

Kuczaj, M. (2001). Interrelations between year season and raw milk hygienic quality indices. *Electronic Journal of Polish Agricultural Universities*, *1*(04), 1.

Martin, P., Vinet, A., Denis, C., Grohs, C., Chanteloup, L., Dozias, D., Maupetit, D., Sapa, J., Renand, G., & Blanc, F. (2021). Determination of immunoglobulin concentrations and genetic parameters for colostrum and calf serum in Charolais animals. *Journal of Dairy Science*, *104*(3), 3240-3249. https://doi.org/10.3168/jds.2020-19423

McGuirk SM, Collins M: Managing the production, storage, and delivery of colostrum. *Veterinary Clinics: Food Animal Practice*, *20*(3), 593-603. https://doi.org/10.1016/j.cvfa.2004.06.005

McGrath, B.A., Fox, P.F., McSweeney P,L,H,. & Kelly, A.L. (2016). Composition and properties of bovine colostrum: A review. *Dairy Science & Technology*, *96*(2), 133-158. https://doi.org/10.1007/s13594-015-0258-x

Morrill, K., Robertson, K., Spring, M., Robinson, A., & Tyler, H. (2015). Validating a refractometer to evaluate immunoglobulin G concentration in Jersey colostrum and the effect of multiple freeze–thaw cycles on evaluating colostrum quality. *Journal of Dairy Science*, 98(1), 595-601. https://doi.org/10.3168/jds.2014-8730

Morrill, K., Conrad, E., Polo, J., Lago, A., Campbell, J., Quigley, J., & Tyler, H. (2012). Estimate of colostral immunoglobulin G concentration using refractometry without or with caprylic acid fractionation. *Journal of Dairy Science*, *95*(7), 3987-3996. https://doi.org/10.3168/jds.2011-5104

Moore, M., Tyler, J.W., Chigerwe, M., Dawes, M.E., & Middleton, J.R. (2005). Effect of delayed colostrum collection on colostral IgG concentration in dairy cows. *Journal of the American Veterinary Medicine Association*, *226*(8), 1375-1377. https://doi.org/10.2460/javma.2005.226.1375

Navratilova, P., Janstova, B., Glossova, P., & Vorlova, L. (2006). Freezing point of heat-treated drinking milk in the Czech Republic. *Czech Journal of Food Sciences, 24*(4), 156. https://doi.org/10.17221/3313-CJFS

Norberg, E., Hogeveen, H., Korsgaard, I., Friggens, N., Sloth, K., & Løvendahl, P. (2004). Electrical conductivity of milk: Ability to predict mastitis status. *Journal of Dairy Science, 87*(4), 1099-1107. https://doi.org/10.3168/jds.S0022-0302(04)73256-7

Smolenski, G., Haines, S., Kwan, F.Y-S., Bond, J., Farr, V., Davis, S.R., Stelwagen, K., & Wheeler, T.T. (2007). Characterisation of host defence proteins in milk using a proteomic approach. *Journal of Proteome Research, 6*(1), 207-215. https://doi.org/10.1021/pr0603405

Stelwagen, K., Carpenter, E., Haigh, B., Hodgkinson, A., & Wheeler, T. (2009). Immune components of bovine colostrum and milk. *Journal of Animal Science, 87*(13), 3-9. https://doi.org/10.2527/jas.2008-1377

Topal, O., Batmaz, H., Mecitoğlu, Z., & Uzabaci, E. (2018). Comparison of IgG and semiquantitative tests for evaluation of passive transfer immunity in calves. *Turkish Journal of Veterinary & Animal Sciences, 42*(4), 302-309. https://doi.org/10.3906/vet-1712-43

Turini, L., Conte, G., Bonelli, F., Sgorbini, M., Madrigali, A., & Mele, M. (2020). The relationship between colostrum quality, passive transfer of immunity and birth and weaning weight in neonatal calves. *Livestock Science, 238*, 104033. https://doi.org/10.1016/j.livsci.2020.104033

Walstra, P. (1999). Dairy technology: principles of milk properties and processes. *IJDT, 60*(2), 154-154.

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